Key points

- OSA is an increasingly prevalent disorder which has significant systemic effects if left untreated.

- Anatomical abnormalities can be corrected surgically to good effect with a growing and robust evidence base.

- Drug-induced sleep endoscopy is a key tool in the otolaryngologist's armamentarium to tailor specific surgery to address specific anatomical concerns, and to facilitate appropriate patient selection.

- Multilevel surgical approaches are often indicated instead of a "one size fits all" model.

Educational aims

- To discuss how to assess patients presenting with OSA in clinic, from an otorhinolaryngology perspective.

- To discuss the indications for intervention.

- To provide an overview of nonsurgical interventions for treating OSA, with evidence.

- To discuss the different surgical modalities available for treatment of OSA, with evidence.

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Tailoring surgical interventions to treat obstructive sleep apnoea: one size does not fit all

While continuous positive airway pressure (CPAP) remains the gold standard treatment of choice in patients with moderate or severe obstructive sleep apnoea (OSA), surgery has been established as a means to improve compliance and facilitate the use of CPAP, both of which are potential pitfalls in the efficacy of this treatment modality. In a minority of cases, with obvious oropharyngeal anatomical obstruction, corrective surgery may completely alleviate the need for CPAP treatment. In this review, we summarise clinical assessment, surgical options, discuss potential new treatments, and outline the importance of investigating and addressing the multiple anatomical levels that can contribute to OSA. Research into effectiveness of these procedures is rapidly accumulating, and surgery can be an effective treatment. However, given the myriad of options available and multiple levels of anatomical pathology that can present, it is imperative that correctly selected patients are matched with the most appropriate treatment for the best outcomes.

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OSA is an increasingly prevalent disorder with significant systemic effects if left untreated. Anatomical pathology can be corrected surgically with a robust and growing evidence base. Drug-induced sleep endoscopy is a key diagnostic step. http://ow.ly/JZvl30lty23

Introduction

Sleep-related breathing disorders comprise a myriad of conditions, ranging from simple snoring to severe obstructive sleep apnoea (OSA), wherein recurrent partial or complete cessation of breathing occurs. The impact of OSA manifests not only in terms of health outcomes of the sufferers (*e.g.* increases in all-cause mortality, and OSA is a separate risk factor for cerebrovascular and cardiovascular disease) [1, 2], but also has been shown to increase road traffic accidents [3] and exert a large socioeconomic burden on society [4]. It affects 1–2% of women and 2–4% of men [5], although some authors suggest that significant proportions go undiagnosed [6]. More recent data, published by Heinzer *et al.* [7] in 2015, suggests a far greater prevalence, as high as 23.4% in women and 49.7% in men. Symptoms include: characteristic apnoeic episodes of breath-holding during sleep in association with snoring, often noticed by a partner; daytime somnolence; waking up feeling un-refreshed; and impaired cognitive function, *e.g.* poor concentration and memory, may also feature.

Risk factors for this disorder are multifactorial: with age [8], smoking [9] and male sex [10] all being implicated. Anatomical considerations are largely obesity-driven, underpinned by excess

adiposity around the upper airway causing collapse, together with obesity reducing residual functional capacity when asleep by compromising lung volume [11]. Other anatomical considerations include retrognathia and external deformity of the nose with an obvious impact on airflow. Within the internal upper airway, there may be an abnormality inside the nose such as a deviated nasal septum or nasal polyps, or inside the mouth such as a floppy soft palate or large tonsils and tongue.

In the UK, National Institute for Health and Care Excellence (NICE) guidelines recommend nasal continuous positive airway pressure (CPAP) as the first line gold standard treatment for moderate-to-severe OSA [12], consistent with the American College of Physicians guidelines [13]. CPAP, whilst effective, is associated with poor compliance with adherence rates varying from 40% to 85% [14–16].

Therefore, a metaphorical philosopher's stone presents itself in the need for a safe therapeutic intervention for OSA able to circumvent compliance issues, with long-term efficacy and low complication rates. Surgery is an evolving and adaptable intervention, able to address site-specific anatomical considerations in appropriately and carefully selected patients. In this review, we aim to discuss and provide an overview of some of the techniques currently in use in the management of OSA, together with some of the evidence supporting their use. The paucity of level I evidence with long-term outcome measures can hinder progress, yet is reflective of the specialty of surgery in general and much is being done to address this. In addition, further limitations in the extrapolation of results from such studies stem from the huge variety in procedures, together with multiple outcome measures used in assessing efficacy, and a lack of standardisation [17]. This is one of the factors argued by critics such as Elshaug et al. [18], who advocate conservative management over surgical intervention in OSA, suggesting that surgery should not be first line and should instead be reserved for use solely in randomised controlled trials. Nevertheless, surgery has been shown to improve compliance with CPAP, with robust studies of differing modalities showing definite improvements in end goals. One such example is a meta-analysis by Camacho et al. [19] showing a statistically significant reduction in CPAP pressure requirement, as well as improving usage as a result of isolated nasal surgery [16, 19]. Certainly, surgery is not indicated for every patient, and a multilevel, multidisciplinary approach is vital with the otolaryngologist being ideally placed to evaluate and rectify upper airway anatomical pathology.

Assessment in the clinic

Clinical evaluation is vital, as outlined above, with the necessary symptoms, risk factors and skeletal framework abnormalities being identified. Nasal symptoms (including presence of allergic rhinitis)

should be discussed, together with questions regarding the presence of any mouth breathing, which can further compromise the size of the airway and exacerbate palato–pharyngeal vibrations.

We would advocate all patients to undergo an Epworth Sleepiness Scale (ESS) [20] with a higher score denoting greater symptom burden. The STOP-Bang Questionnaire [21] is an alternative validated tool that can be used to screen for OSA.

All patients must have neck collar size and body mass index (BMI) evaluated. Inspection of the face may identify retrognathia, maxillary retrusion or an obvious external nasal framework deformity. Anterior rhinoscopy will identify any proximal nasal defects such as caudal dislocation of the nasal septum contributing to symptoms. It is, however, imperative to perform flexible nasopharyngolaryngoscopy to assess the upper airway in detail, making note of any nasal problems such as deviated septum (figure 1), polyposis (figure 2), bulky tongue base, or the presence of redundant pharyngeal folds. Furthermore, examination of the oropharynx is advised, taking into account the size of palatine tonsils if present, length of soft palate and uvula (figure 3). The Mallampati score [22] and Friedman tongue position grading [23] are useful tools. With the endoscope in position, the Müller's manoeuvre (reversed Valsalva manoeuvre) can be performed to get some idea of the level as well as degree of upper airway obstruction.
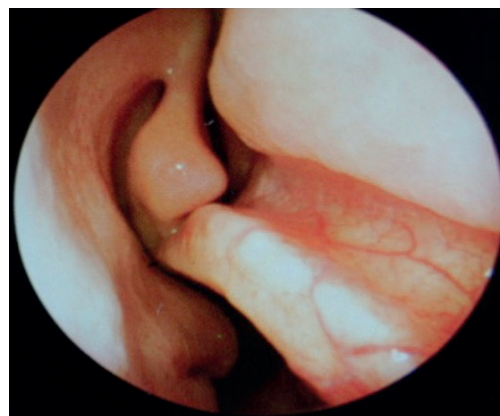

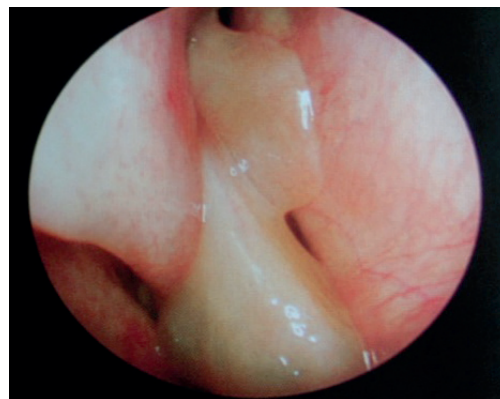**Figure 1** *Endoscopic view of septal deviation.*

Figure 2 *Endoscopic view of nasal polyps.*

Figure 3 *Oropharyngeal crowding.*

Investigations

First and foremost, it is imperative to ascertain a diagnosis of OSA with either hospital-based polysomnography or an ambulatory home sleep study. Various useful parameters can be gauged, such as the apnoea–hypopnoea index (AHI), which stratifies severity of OSA into mild (5–<15 events·h^{-1}), moderate (15–<30 events·h^{-1}), and severe (>30 events·h^{-1}).

First pioneered in 1991 [24], drug-induced sleep nasendoscopy (DISE) is the investigation of choice in the surgical assessment of sleep disordered breathing. It allows for a dynamic and three-dimensional assessment of upper airway obstruction at multiple levels, facilitating surgical planning and tailoring the most appropriate treatments. The procedure is carried out jointly by the anaesthetist and surgeon in an operating theatre, with midazolam and propofol being the commonly used sedative agents to induce sleep, followed by insertion of the nasendoscope to systematically assess anatomical obstruction of the upper airway during sleep. Continuous monitoring of oxygen saturations and cardiovascular parameters are maintained in theatre while the procedure is carried out. Manoeuvres such as mouth closure and jaw lift can also be used to ascertain if these have any effect on anatomy and airflow, thus suggesting that a chin-strap or a mandibular advancement device may resolve the upper airway obstruction.

Some argue that DISE does not mimic natural sleep, and that the technique is further limited by subjectivity of the assessment. Proponents of the technique argue that the sedation administered elicits the same effect on all levels of the upper airway, and thus it can still be used effectively to evaluate the proportion of obstruction encountered at each level. Furthermore, progress has been made in standardising the assessment. Bispectral Index (BIS) monitoring has also emerged as useful tool in enhancing reliability of anaesthetic protocols, in particular to ascertain the correct depth of sedation for the procedure (figure 4) [25]. BIS uses electroencephalological parameters to statistically generate a number ranging from 0 to 100 to gauge the depth of sedation. One of the various manufacturing firms, Covidien, state in their clinicians' guidance that the number generated is a continuum which can denote a clinical correlation as follows: 100 suggests an awake state, 80 light/moderate, 60 general anaesthesia, 40 a deep hypnotic state, and 0 a flatline EEG (http://www.covidien.com/imageServer.aspx/doc252087.pdf?contentID=77508&contenttype=application/pdf).

In those trained in the technique and interpretation of findings, DISE forms the fundamental bedrock of surgical planning. This has been corroborated by studies showing improved surgical outcome data in OSA patients undergoing laser-assisted palatoplasty with or without tonsillectomy, having been assessed using DISE and thus offered target-specific surgery [26].

Efforts to standardise DISE have been made. In 2014, a consensus was arrived at following a meeting of a panel of European experts, outlining critical pre-procedural investigations and key steps, *e.g.* BIS monitoring for depth of sedation, avoidance of local anaesthetic and anti-secretion agents [25].

Further information surrounding the use of DISE can be found in the thorough review article by LECHNER *et al*. [27], where the argument for a gold standard in DISE is made together with recommendations for optimal technique.

Nonsurgical treatment and the reasons for surgical intervention

CPAP

As outlined above, CPAP remains the treatment of choice for moderate-severe OSA as per NICE guidelines. Nevertheless, compliance rates can be poor. In addition, there are anatomical confounders to effective CPAP such as nasal septal deviation, nasal valve collapse, turbinate hypertrophy and adenoidal hypertrophy. Apart from the purely structural pathology requiring surgery, some of these include an inflammatory component, *e.g.* turbinate
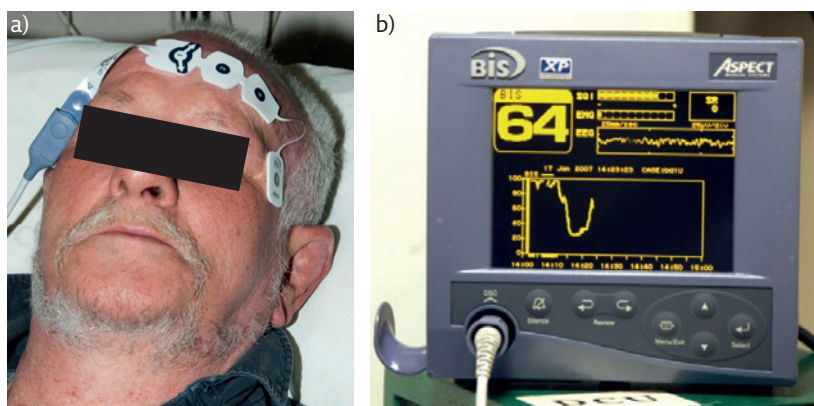

Figure 4 *a) Bispectral Index (BIS) electrodes attached to a patient. b) The BIS monitor.*

hypertrophy, that may be treated medically (*e.g.* topical intranasal steroids, antihistamines or saline nasal douching), leading to improved CPAP compliance with reduced pressure requirements but rarely complete resolution of OSA [28].

Lifestyle modification

Not only do weight loss strategies reduce the incidence of significant OSA [29], our local guidelines stipulate patients have a BMI <35 kg·m^{-2} to be considered for surgical intervention, with an optimal BMI of <32 kg·m^{-2}.

Appliances and other nonsurgical modalities

Patients with retrognathia or those with tongue base collapse improving with jaw lift on DISE may benefit from a mandibular advancement splint (MAS) device, which can be a standalone treatment for mild-to-moderate OSA [30, 31]. However, they can be poorly tolerated, and are contraindicated in patients with poorly controlled epilepsy, temporomandibular joint problems and poor dentition [32].

Surgical management

The decision to offer surgery should be based on the correct selection of patients, with robust preoperative consenting and explanation of the associated risks. It is important to counsel patients about what the surgery is trying to achieve, and that the gold standard treatment for OSA is CPAP. The fact that the surgery could be curative or merely adjunctive in facilitating CPAP use must be explained. Furthermore, post-operative pain management and potential feeding problems must be explained at length to patients, in particular for those undergoing more radical palatal surgery.

As per Ferguson *et al*. [33], at our institution and based on our experience, we group our patients into three categories in whom we would offer surgery based on AHI-stratified severity of OSA: 1) mild OSA with raised flow limitation indices (indicating resistance to airflow based on anatomical abnormalities) >15%; 2) moderate or severe OSA not tolerating CPAP and failing a trial of MAS (surgery being adjunctive to aid delivery and facilitation, and thereby compliance with CPAP); 3) moderate or severe OSA, not tolerating CPAP (surgery with curative intent, aiming to improve AHI to <15 events·h^{-1}) [33]. DISE is imperative in patient selection/treatment planning as outlined previously, especially given the multilevel patterns of obstruction often seen in patients with OSA.

The main aim of surgery is to improve upper airway dimensions and hence reduce obstruction. Interventions can be said to be adjunctive (reducing CPAP requirements and improving compliance) or curative and can be further categorised into minimally invasive *versus* radical approaches, or single site *versus* multilevel anatomical approaches.

Minimally invasive surgery includes the injection of chemicals to induce scarring as well as radiofrequency thermotherapy to the soft palate and tongue base. The more radical treatments include uvulopalatopharyngoplasty (UPPP), laser-assisted uvulopalatoplasty (LAUP), expansion sphincter palatoplasty, palatal advancement flaps, and tongue base surgery. These will be discussed in the following sections, classified anatomically.

Nasal surgery

Surgical procedures include septoplasty, septorhinoplasty, nasal valve surgery, functional endoscopic sinus surgery, and turbinate reduction surgery. These all aim to bypass sources of anatomical obstruction. It is worth remembering that nasal surgery rarely eliminates the need for CPAP, but may facilitate its delivery and hence compliance. A meta-analysis has corroborated this finding, showing that nasal surgery can reduce CPAP pressure requirements and improve discomfort levels [19]. Despite the fact that surgery to overcome nasal obstruction is associated with significant improvements in life quality, this alone has not correlated with a tangible improvement in polysomnographic data [34].

Pharyngeal morphology has been shown to have a bearing on efficacy of nasal surgery in patients with OSA or nasal obstruction, with better outcomes noted in those with a widened retroglossal space and a high soft palate (although the clinical usefulness of this in preoperative selection of patients remains unclear) [35].

It must also be borne in mind that nasal complaints feature in more than 50% of CPAP users, with symptoms including congestion, rhinorrhoea and dryness [36]. This may be amenable to medical or surgical treatment and can potentially improve CPAP compliance *via* reduced pressures; therefore, the need to evaluate and optimise these patients thoroughly in clinic is vital.

Oropharyngeal surgery

A myriad of interventions exist at the palatal level in treating patients with OSA. They can be classified into procedures to induce scarring and stiffen the palate (minimally invasive), and procedures altering the shape and dimensions of the palate. Friedman's tongue position has a prognostic bearing on efficacy of palatal surgery, with position 1 being associated with improved outcomes (up to 80.6% success rate following UPPP at 6 months) compared with position 2 or 3 [23].

In terms of minimally invasive interventions, the use of chemical injections (*e.g.* sodium tetradecyl

sulphate) [37] is not advocated at our institution due to a complication profile including palatal ulceration and fistula formation (albeit temporary) and short-lived benefits. Pillar implants have been used to increase the integrity of the soft palate, although the body of evidence supporting its use remains limited owing to limited follow-up [38].

Radiofrequency treatments to the soft palate induce scarring through interstitial thermal trauma and fibrosis [39]. Their use has been approved in the UK by NICE. There is a body of evidence showing their efficacy when used on the soft palate and tongue base in patients deemed "simple snorers" or those with mild OSA. Furthermore, a meta-analysis demonstrated excellent results of radiofrequency thermotherapy alone being maintained for up to 24 months [40]. The intervention is delivered *via* an ablation device, and may be used on its own or in conjunction with other more invasive procedures, *e.g.* tonsillectomy and resection of redundant tonsillar pillars, or shortening of uvula. Repeat applications may be required, but nevertheless complication rates remain low [41]. These include mucosal ulceration, although abscess/fistula has also been reported. Steps can be taken to mitigate this by taking care to ensure that the device is correctly inserted into tissues, and not placed too superficially.

More invasive palatal surgery works to improve the architectural dimensions of the palate, thereby reducing obstruction. The historical days of offering a "one size fits all" radical UPPP are well and truly confined to the past, especially with the move towards rigorous preoperative assessment and surgical planning with DISE. The radical UPPP has been in use since the 1960s, but its modification and renaissance in 1981 has been accredited to Fujita *et al.* [42].

Robust evidence exists in the form of a randomised controlled trial conducted by Browaldh *et al.* [43], undertaken in moderate-to-severe OSA patients undergoing UPPP *versus* those not undergoing surgery, showing that AHI reduced by as much as 60% in those undergoing UPPP compared with the control group. Furthermore, a subsequent analysis of the same trial confirmed that following a modified UPPP, blood pressure was significant decreased post-operatively in patients with moderate-to-severe OSA undergoing surgery, with significant results also noted at 24 months [44]. However, despite various modifications, it remains a painful procedure with complications such as velopharyngeal incompetence and post-operative nasopharyngeal stenosis marring its efficacy, as well as hindering post-operative CPAP compliance. Hence, we instead advocate the less radical procedure of the Kotecha technique LAUP [45, 46]. Our long-term outcomes following LAUP as opposed to UPPP have been very encouraging [47]. Furthermore, the complications encountered with UPPP such as velopharyngeal incompetence and nasopharyngeal stenosis are seen less with LAUP.

Some studies, such as that undertaken by Ryan and Love [48] looking at 44 consecutive patients with mild-to-moderate OSA undergoing LAUP, have questioned the variable efficacy of the procedure. However, in experienced hands and most crucially with the correct preoperative selection of patients using DISE, LAUP has been demonstrated to lead to a 73% reduction in AHI to 12.9 events·h^{-1} at >4 months, together with a reduction in ESS down by a mean of 7.9, in a single-centre study of patients with moderate-severe OSA, not tolerating CPAP [26].

Procut palatoplasty can be employed in conjunction with interstitial radiofrequency to the palate, sometimes also in patients without an abundance of redundant soft palate tissue. Finally, the modified LAUP outlined by Ellis *et al.* [49] may be considered patients in whom AHI has not improved sufficiently following LAUP and where the palate is still deemed to contribute to airway obstruction (this is elucidated by DISE, an important post-operative assessment, together with a sleep study). In addition to this, procedures such as expansion sphincter palatoplasty, whereby palatopharyngeus fibres are divided and rotated anteriorly and anchored with a stitch to the Hamulus, can be effectively undertaken to further prevent lateral collapse with improvements noted in AHI [50, 51].

Tongue base surgery

DISE assessment can often reveal collapse of the base of tongue with or without an epiglottic compromise in the form of a "trap door" phenomenon onto the larynx further compounding tongue base retraction/collapse. It is certainly worth considering this in patients who present having failed palatal surgery.

The minimally invasive radiofrequency treatments discussed earlier induce stiffening and reduce the bulk of the tongue. More invasive options include midline glossectomy. In cases with an epiglottic component, tongue base reduction with hyoid epiglottoplasty can be undertaken as described by Chabolle *et al.* [52] in 1999. If there is evidence of a trap-door phenomenon, midline glossectomy would be accompanied with epiglottic wedge resection. A significant improvement in AHI was noted in ~56% of patients undergoing midline glossectomy in a cohort of 50 patients, with optimum benefit being noted in patients with Friedman tongue position 3 [53]. The nature of the procedure must be emphasised to patients, together with the potential complications which include dysphagia, significant odynophagia, dysphonia and aspiration. Multidisciplinary working can be useful in the form of early speech and language therapy intervention.

Transoral robotic surgery

Encouraging data has been presented on the use of transoral robotic surgery (TORS) in tongue base

surgery [54–56]. For the surgeon, the robotic technique negates any tremor and provides a visual field par excellence with the possibility of multiplanar tissue manipulation. It allows for better access to regions that can present a challenge to approach in terms of location. Limitations include institutional availability of the robot, as well as the surgeon's learning curve to attain proficiency in its usage. Results from Arora *et al.* [57] demonstrated an overall 51% reduction in AHI in a series of 14 patients with moderate-to-severe OSA undergoing TORS to the tongue base, with additional wedge epiglottoplasty in 10 patients. 36% had normal post-operative polysomnography results, with further improvement in quality of life and mean oxygen saturations. Patient selection was strict and comprised those with an AHI of ≥15 events·h^{-1}, with failure to tolerate CPAP and MAS, with a BMI of <35 kg·m^{-2}, and with DISE evidence of tongue base collapse with or without epiglottis collapse. The essential condition of robust and appropriate patient selection for this surgical modality is therefore evident [57].

Further evidence from a recent meta-analysis has also shown a significant reduction in AHI with improved visual analogue scales for snoring and ESS scores in OSA patients undergoing TORS [58].

Hypoglossal nerve

Synchronised stimulation of the hypoglossal nerve with inspiration *via* an electrical implant has been proposed as a means to improve upper airway muscle tone. A landmark multicentre prospective study (the STAR trial) looked at clinical effectiveness and safety of the device. Conducted by Strollo *et al.* [59] and involving 126 participants carefully selected using DISE with exclusion of patients with circumferential collapse of the nasopharynx and oropharynx, from a group of over 900 initially enrolled across the USA and Europe, it investigated upper airway stimulation in patients with OSA and established that AHI decreased significantly following device implantation. The rate of procedure related serious adverse events was found to be less than 2% [59]. Both noninvasive and invasive methods exist. Whilst being an area of interest with promising and significant improvements in OSA symptoms and polysomnography, initial concerns arose following trials of the invasive device, due to serious adverse outcomes including the need to remove or replace the implant due to infection and malfunction [60, 61].

Recent work has been carried out by Steier's team looking at the available evidence in terms of electrical stimulation of upper airway in OSA [62]. Mainly consisting of randomised controlled trials and clinical studies, their review has cemented opinion that this technique can be useful for selected patients, *i.e.* those who tolerate CPAP poorly, with good results. A variety of devices exist, but the first to be developed and trialled on humans was the Inspire device (Inspire Medical Systems TM, Maple Grove, MN, USA). This system (implanted under general anaesthesia) consisted of an implantable pulse generator, a stimulation electrode and a respiratory pressure sensor in contact with the pleura to detect respiratory effort, with the end phase of expiration triggering the pulse generator at the start of inspiration. As briefly mentioned earlier, despite promising early results, device malfunction and broken electrodes in five out of eight patients meant that the use of this device was limited to the study [61]. This led to a focus on improving technology with many new systems and devices being created, and studies showing promising results [62].

This is an expanding field with advances being made in terms of different methods of stimulation, technical/device improvements, and hybridisation of invasive and noninvasive techniques. In terms of the latter, a clinical trial has been conducted with results soon to be published looking into the efficacy and safety of the Nyxoah system (Nyxoah S.A., Brussels, Belgium) consisting of an implantable stimulator (Genio TM Implantable Stimulator; Nyxoah S.A.) to be positioned in the submental area with an activation chip attached to the skin (https://clinicaltrials.gov/ct2/show/NCT02312479). Benefits include bilateral stimulation of the hypoglossal nerve through the one system, together with the minimally invasive technique of implantation compared with other methods.

Ultimately, the conclusion to be drawn is that for individuals with moderate-to-severe OSA failing medical therapy and having undergone DISE assessment of the anatomical level of obstruction, hypoglossal nerve stimulation has been shown to be safe and effective and can improve outcomes measures including AHI, ESS and quality of life [62].

Hyoid suspension

This technique (whereby the hyoid bone together with its attachments to the tongue and upper airway can be advanced forwards and upwards towards the mandible, or forwards and downwards towards thyroid cartilage, in order to improve airway dynamics by increasing airway size and patency) tends to be used more often in multilevel surgery. It may prevent hypopharyngeal collapse of the tongue during sleep. When used in isolation, however, success rates are as low as 17% [63]. Furthermore, significant complications are reported, including dysphagia and speech difficulties [34].

Tracheostomy

This can be used as an adjunctive tool for airway support during upper airway procedures, and also as permanent, curative (albeit last resort) surgery for OSA. Success rates are the highest of any surgical intervention for OSA, yet the implications for the patient are significant. In addition, the

anatomical challenges of performing tracheostomy on this group of patients, many of whom have a raised BMI, are considerable. Notwithstanding, mortality rates have been shown to reduce post-operatively, and it can improve the quality of life of some patients [64].

Maxillomandibular advancement surgery

This skeletal framework surgery is invasive and associated with significant immediate post-operative morbidity, such as the need for a soft diet for 2 months post-operatively. Yet the surgery itself is associated with almost comparable success rates to tracheostomy in treating OSA [65, 66]. Complication rates, while being low, can be serious [67]. Other options include rapid maxillary expansion, which has been shown to increase maxillary width and thereby reduce nasal resistance. The mainstay of its use is as a paediatric orthodontic treatment for maxillary constriction, but some authors report a significant reduction in AHI among young adults with mild or moderate OSA [68].

Bariatric surgery

The risk factor of obesity underpins OSA, and bariatric surgery addresses this specifically. Various operations exist, such as Roux-en-Y gastric bypass and vertical banded gastroplasty, which may facilitate weight loss as outlined in the review by Kotecha and Hall [34]. It must be remembered that weight loss does not always result in a cure for OSA. In addition, the data supporting improvement in AHI post-bariatric surgery is limited, despite improving sleep quality [5, 11]. Indeed, retrospective cohort studies in bariatric surgery exist showing potential benefit in the treatment of OSA, but again these are not curative [69]. Other cohort studies show improvement in terms of lowering CPAP pressure in patients following bariatric surgery at 11 months post-intervention, which may facilitate CPAP compliance [70]. Opinion remains divided on this issue: a randomised controlled trial investigating patients with moderate/severe OSA undergoing laparoscopic adjustable gastric banding showed that despite promising early results with significant post-operative AHI reduction, there was no statistically significant reduction in AHI at 2 years compared with a conventional weight loss programme, which is worth bearing in mind when considering what can and cannot be achieved by this type of surgery [71].

Conclusion

The variety of options available to treat sleep disordered breathing presents a surgical cornucopia. However, when these interventions do not address the specific anatomical problems causing the pathology conflict arises, ultimately limiting efficacy for the patient. We have reached an era in which site-specific and targeted surgery can and must be offered. This is only possible with rigorous and correct patient selection, with the use of DISE.

The surgical evidence base in this area, as with all surgical specialties, is growing. We believe that there is a mandate to further this with more high-quality research with long-term follow-up, but also standardised definitions of success in terms of reporting outcomes. In addition, the adoption of patient-reported outcome measures together with objective polysomnographic assessments is critical. Furthermore, a multidisciplinary approach is essential, given the nature of this pathology. After every intervention, we advocate reassessments and re-evaluations, with DISE being critical. We would therefore advise that all patients failing a CPAP trial should be referred for evaluation by the otolaryngologist. Surgical advances and evolving techniques are pivotal to developments in this field.

Self-evaluation questions

1. Surgery for upper airway obstruction can address anatomical problems in which location(s) within the upper airway (select all that apply)?
   a) Nose
   b) Soft palate
   c) Base of tongue
   d) Epiglottis
2. Can nasal surgery alone facilitate CPAP delivery and utilisation?
   a) True
   b) False
3. In which of these scenarios is there a role for hypoglossal nerve stimulation in sleep-related breathing disorders?
   a) Moderate obesity
   b) Isolated palatal obstruction
   c) Circumferential collapse of the upper airway
   d) Tongue base and hypopharyngeal obstruction without the presence of an oropharyngeal or nasal component
4. Which of the following is/are an evidence-based evaluation technique that is useful in the assessment of sleep disordered breathing (select all that apply)?
   a) Computed tomography
   b) Magnetic resonance imaging
   c) Pressure transducer (e.g. ApneaGraph)
   d) Cephalometry
   e) Acoustic manometry
   f) Drug-induced sleep nasendoscopy
5. What is the role for surgery, if any, in the treatment of sleep disordered breathing?
   a) Adjunctive
   b) Curative
   c) Both adjunctive and curative
   d) No role

We are bearing witness to promising advances in this fascinating area, from the expanding evidence base to emerging surgical technology, with the scope and aim to improve outcomes for patients by delivering innovative, targeted, site-specific interventions.

Conflict of interest

None declared.

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Suggested answers

1. a–d.
2. a.
3. d.
4. c and f.
5. c.